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   9711771.7 — -5 JUN 1997

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   ROLLS-ROYCE plc
   65 BUCKINGHAM GATE
   LONDON SW1E 6AT

   Patents ADP number *(if you know it)* 00003970002

   If the applicant is a corporate body, give the country/state of its incorporation

   ENGLAND

4. Title of the invention

   A ROTOR

5. Name of your agent *(if you have one)*

   M A GUNN

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

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   PATENTS DEPARTMENT
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   DERBY DE24 8BJ

   Patents ADP number *(if you know it)*

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Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

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Description	11
Claim*(s)*	3
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Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	2
Request for preliminary examination and search *(Patents Form 9/77)*	1
Request for substantive examination *(Patents Form 10/77)*	1
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11. I/We request the grant of a patent on the basis of this application.

Signature M A Gunn Date

M A GUNN 2.6.97

12. Name and daytime telephone number of person to contact in the United Kingdom

T A LITTLE 01332 249397

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1. Your reference

DY 2581

2. Patent application number
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3. Full name of the or of each applicant

ROLLS-ROYCE plc

4. Title of the invention

A ROTOR

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1 TELFORD CLOSE
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A ROTOR

The present invention relates to a rotor, particularly to a rotor for compressors and turbines of gas turbine engines, but may be useful for compressors and turbines of steam turbines etc.

The compressors of gas turbine engines generally comprise a plurality of compressor rotor discs which are interconnected by one or more axially extending annular spacers. Each compressor rotor disc carries an associated stage of compressor rotor blades which are circumferentially spaced and which extend radially from the rotor disc. The rotor blades have tips and a compressor casing surrounds the rotor blades. The tips of the rotor blades are spaced radially from the compressor casing by a clearance. The annular spacers also have one or more circumferentially extending ribs which form a labyrinth seal with an associated stator vane supported by the compressor casing. The compressor rotor discs and associated compressor rotor blades are designed to lie in a radial plane.

A problem associated with these compressors is that in operation the annular spacers move radially outwardly more than the compressor rotor disc, generally the annular spacers bow radially outwardly, due to centrifugal force and this causes the compressor rotor disc, and the associated stage of compressor rotor blades, at the downstream end of the spacers to lie at an angle relative to the radial plane.

This may result in rubbing between the leading edges of the tips of the rotor blades and the compressor casing and the trailing edges of the tips of the rotor blades moving away from the compressor casing. This radial movement of the annular spacers is undesirable because it adversely effects

the clearance between the tips of the rotor blades and the compressor casing. The rubbing between the leading edges of the blade tips at maximum speed of the engine may cause significant wear in the compressor casing and/or rotor blade tip resulting in an increased clearance at lower speeds and therefore increased leakage of working fluid passed the tips of the rotor blades and hence loss of efficiency of the compressor and gas turbine engine.

A further problem associated with the annular spacers moving radially outwardly more than the compressor rotor disc, generally the annular spacers bow radially outwardly, due to centrifugal force, is that it causes rubbing between the circumferentially extending ribs which form the labyrinth seal and the associated stator vane. This radial movement of the annular spacers is undesirable because it adversely effects the clearance between the circumferentially extending ribs and the associated stator vane. The rubbing between the circumferentially extending ribs and the associated stator vane at maximum speed of the engine may cause significant wear in the stator vane and/or ribs resulting in an increased clearance at lower speeds and therefore increased leakage of working fluid passed the ribs and hence loss of efficiency of the compressor and gas turbine engine.

Accordingly the present invention seeks to provide a rotor which reduces the above mentioned problem.

Accordingly the present invention provides a rotor comprising a plurality of axially spaced rotor discs, each rotor disc having a plurality of rotor blades extending radially therefrom, a stator spaced from the rotor by a clearance, at least one annular spacer extending axially between and secured to an upstream rotor disc and a downstream rotor disc, the at least one annular spacer being

fibre reinforced to limit the radial movement thereof and hence the clearance between the rotor and the stator.

Preferably the stator comprises a casing surrounding and spaced radially from the rotor blades by a clearance, the at least one annular spacer being fibre reinforced to limit the radial movement thereof and hence the clearance between the rotor and the stator.

Preferably the stator comprises a stator vane assembly surrounding and spaced radially from the annular spacer by a clearance, the at least one annular spacer being fibre reinforced to limit the radial movement thereof and hence the clearance between the rotor and the stator.

Preferably the annular spacer has at least one circumferentially extending rib to define a labyrinth seal with the stator vane assembly.

Preferably the rotor discs are metal discs and the at least one annular spacer is a fibre reinforced metal spacer.

Preferably the rotor discs are fibre reinforced metal discs, the fibre reinforced metal disc being reinforced by at least one ring of fibres. Preferably the fibre reinforced metal disc has an axis of rotation, the fibre reinforced metal disc has a first ring of fibres at a first radial distance from the axis of rotation and a second ring of fibres at a second radial distance from the the axis of rotation, and the second radial distance is greater than the first radial distance. Preferably the fibre reinforced metal disc comprises a hub, a rim and a diaphragm extending radially between the hub and the rim, the first ring of fibres is in the hub of the fibre reinforced metal disc and the second ring of fibres is in the rim of the fibre reinforced metal disc.

Preferably the fibre reinforced metal disc comprises titanium, titanium aluminide, an alloy of titanium, or any suitable metal, alloy or intermetallic which is capable of being bonded.

Preferably the fibre reinforced metal spacer comprises titanium, titanium aluminide, an alloy of titanium, or any suitable metal, alloy or intermetallic which is capable of being bonded.

Preferably the reinforcing fibres comprise silicon carbide, silicon nitride, boron, alumina or other suitable fibres.

Preferably there are a plurality of annular spacers.

The fibre reinforcement in the annular spacer may be selected to provide sufficient stiffness to the annular spacer to minimise radially outward movement of the annular spacer relative to the upstream rotor disc and downstream rotor disc. Preferably the fibre reinforcement in the annular spacer is selected to provide sufficient stiffness to the annular spacer to match the radially outward movement of the annular spacer, the upstream rotor disc and the downstream rotor disc.

The fibre reinforcement may be selected to provide sufficient stiffness to the annular spacer to produce radially inward movement of the annular spacer relative to the upstream rotor disc and downstream rotor disc.

The rotor may be a compressor rotor or a turbine rotor. The rotor may be a gas turbine rotor.

The present invention will be more fully described by way of example with reference to the accompanying drawings, in which:-

Figure 1 is a cross-sectional view through a conventional compressor rotor.

Figure 2 is a cross-sectional view through a compressor rotor according to the present invention.

Figure 3 is a cross-sectional view through an alternative compressor rotor according to the present invention.

Figure 4 is a cross-sectional view through a gas turbine engine having a rotor according to the present invention.

A conventional compressor rotor 10, as shown in figure 1, comprises a plurality of solid metal compressor discs, in this example a first, upstream, compressor disc 12 and a second, downstream, compressor disc 14. The compressor discs 12 and 14 are spaced apart by an annular spacer 16 which extends axially between and is secured to the compressor discs 12 and 14. The rim of the compressor disc 12 carries a plurality of equi-circumferentially spaced radially extending compressor rotor blades 18. The rim of the compressor disc 14 carries a plurality of equi-circumferentially spaced radially extending compressor rotor blades 20. The compressor rotor blades 18 and 20 may be integral with the rim or the compressor blades may have roots which are arranged to locate in axially or circumferentially extending grooves, not shown, in the rim of the compressor discs 12 and 14. The compressor rotor blades 18 and 20 which are integral with the rim may be friction welded to the rim or may be machined from the forged disc.

The compressor discs 12 and 14 and the compressor rotor blades 18 and 20 are designed to lie in radial planes A relative to the axis of rotation X of the compressor rotor 10.

A compressor casing 22 surrounds the compressor rotor 10 and the compressor casing 22 is spaced radially from the tips of the compressor rotor blades 18 and 20 by clearances 24 and

26 respectively. The annular spacer 16 has a plurality of circumferentially and radially extending ribs 28. The compressor casing 22 carries a plurality of stator vane assemblies, only one of which is shown. Each stator vane assembly comprises a plurality of equi-circumferentially spaced stator vanes 30 and the radially inner shrouds 32 of the stator vanes 30 cooperate with the ribs 28 on the annular spacer 26 to form a labyrinth seal. The ribs 28 are spaced from the inner shrouds 32 by a clearance 34. The inner shrouds 32 usually comprise a honeycomb or abradable material which is in proximity to the ribs 28.

In operation the centrifugal force acting on the rotor 10 causes the annular spacers 16 to move radially by more than the compressor discs 12 and 14 such that they become bowed radially outwardly. This causes the second, downstream, compressor disc 14 and the compressor blades 20 to lie at an angle relative to the radial plane A. In particular the radially outer tips 36 of the compressor blades 20 move in a radially downstream direction relative to the radially inner ends of the compressor blades 20. This causes the leading edges 38 of the radially outer tips 36 of the compressor blades 20 to move radially outwardly and the trailing edges 40 of the radially outer tips 36 of the compressor blades 20 to move radially inwardly. The resulting radially outward movement of the leading edges 38 of the radially outer tips 36 of the compressor blades 20 may produce rubbing between the leading edges 38 of the tips 36 and the compressor casing 22 particularly at high operating speeds. The rubbing may wear away part of the compressor casing 22 to form trenches or wear away the blade tips 36 and hence increase the clearance 26 and leakage flow through the clearance 26 at lower operating speeds. This therefore may

decrease the efficiency of the compressor and hence the efficiency of the gas turbine engine.

Also the radially outward movement of the annular spacers 16 causes rubbing between the circumferentially extending ribs 28 and the inner shroud 32 of the associated stator vanes 30 which form the labyrinth seal. This radial movement of the annular spacers 16 is undesirable because it adversely effects the clearance 34 between the circumferentially extending ribs 28 and the associated inner shrouds 32 of the stator vanes 30. The rubbing between the circumferentially extending ribs 28 and the inner shrouds 32 of the stator vanes 30 at maximum speed of the engine may wear away part of the inner shroud 32 of the stator vanes 30 and/or the ribs 28 resulting in an increased clearance 34 at lower speeds and therefore increased leakage of working fluid passed the ribs 28 and hence loss of efficiency of the compressor and gas turbine engine.

Also the radial movement of the annular spacer 16 causes the compressor blades 20 to lie at an angle relative to the plane A. This may cause the trailing edges 40 of the compressor blades 20 to touch the leading edges of an adjacent stage of stator vanes.

A compressor rotor 40 according to the present invention, as shown in figure 2, comprises a plurality of solid metal compressor discs, in this example a first, upstream, compressor disc 42 and a second, downstream, compressor disc 44. The compressor discs 42 and 44 are spaced apart by an annular spacer 46 which extends axially between and is secured to the compressor discs 42 and 44. The rim of the compressor disc 42 carries a plurality of equi-circumferentially spaced radially extending compressor rotor blades 48. The rim of the compressor disc 44 carries a

plurality of equi-circumferentially spaced radially extending compressor rotor blades 50. The compressor rotor blades 48 and 50 may be integral with the rim or the compressor blades may have roots which are arranged to locate in axially or circumferentially extending grooves, not shown, in the rim of the compressor discs 42 and 44. The compressor rotor blades 48 and 50 which are integral with the rim may be friction welded to the rim or may be machined from the forged disc.

The compressor discs 42 and 44 and the compressor rotor blades 48 and 50 are designed to lie in radial planes A relative to the axis of rotation X of the compressor rotor 40.

A compressor casing 52 surrounds the compressor rotor 40 and the compressor casing 52 is spaced radially from the tips of the compressor rotor blades 48 and 50 by clearances 54 and 56 respectively. The annular spacer 46 has a plurality of circumferentially and radially extending ribs 58. The compressor casing 52 carries a plurality of stator vane assemblies, only one stator vane assembly is shown. Each stator vane assembly comprises a plurality of equi-circumferentially spaced stator vanes 60 and the radially inner shrouds 62 of the stator vanes 60 cooperate with the ribs 58 on the annular spacer 46 to form a labyrinth seal. The ribs 58 are spaced from the inner shrouds 62 by a clearance 64. The inner shrouds 62 usually comprise a honeycomb or abradable material which is in proximity to the ribs 58.

The annular spacer 46 differs from that in figure 1 in that a ring of fibres 72 is provided to reinforce the annular spacer 46. The fibres are ceramic fibres and extend circumferentially through 360 degrees. This results in an increase in the stiffness of the annular spacer 46. The

stiffness of the annular spacer 46 is controlled by the amount of reinforcing fibres in the ring of fibres 72, the size and the position of the ring of fibres 72 within the annular spacer 46. The ring of fibres 72 is selected to minimise the amount of radial movement, or radial bowing, of the annular spacer 46 relative to the compressor discs 42 and 44 in operation, and preferably the ring of fibres 72 is selected such that there is no radial movement of the annular spacer 72 relative to the compressor discs 42 and 44. This is achieved by selecting the ring of fibres 72 so that the radial movement of the annular spacer 46 matches the radial movement of the compressor discs 42 and 44.

In operation the annular spacer 72 minimises the amount of movement of the radially outer tips 66 of the compressor blades 50 in a radially downstream direction relative to the radially inner ends of the compressor blades 50. This minimises the movement of the leading edges 68 of the radially outer tips 66 of the compressor blades 50 radially outwardly and minimises the movement of the trailing edges 70 of the radially outer tips 36 of the compressor blades 50 radially inwardly. This minimises the possibility of rubbing between the leading edges 68 of the radially outer tips 66 of the compressor blades 50 and the compressor casing 52 particularly at high operating speeds, and hence minimises the possibility of forming trenches and hence maintains the clearance 66 closer to the designed clearance. Thus the efficiency of the compressor and hence the efficiency of the gas turbine engine is maintained.

Also the spacer 72 minimises the amount of radial movement of the ribs 58 on the annular spacer 72 relative to the inner shrouds 62 of the stator vanes 60. This minimises the possibility of rubbing between the ribs 58 and the inner

shrouds 62 of the stator vanes 60 particularly at high operating speeds, and hence minimises the possibility of wearing trenches in the honeycomb or abradable material or wearing the ribs 58. Furthermore this maintains the clearance 64 closer to the designed clearance and thus the efficiency of the compressor and hence the efficiency of the gas turbine engine is maintained.

Additionally fouling between the trailing edges 70 of the compressor blades 50 and an adjacent stage of stator vanes is prevented. Furthermore, the use of the ring of fibres 72 in the annular spacer 46 results in the compressor discs 42 and 44 having reduced weight because the discs do not require additional material to give some radial movement control to the annular spacer 46.

Another compressor rotor 80 according to the present invention, as shown in figure 3, comprises one or more fibre reinforced metal compressor discs, in this example a first, upstream, compressor disc 42 and a second, downstream, compressor disc 44. The compressor rotor 80 is substantially the same as that in figure 2, but the second compressor disc 44 is a fibre reinforced metal disc and comprises a first ring of fibres 74 and a second ring of fibres 76. The first ring of fibres 74 is arranged at a first radial distance from the axis of rotation X in the hub 78 of the disc 44 and the second ring of fibres 76 is arranged at a second radial distance from the axis of rotation X in the rim 80 of the disc 44. The hub 78 and rim 80 are interconnected by a diaphragm 82. The first and second rings of fibres 74 and 76 minimise the weight of the compressor disc 44. The fibres are ceramic fibres and extend circumferentially through 360 degrees. The annular spacer 72 works exactly the same as for the embodiment in figure 2.

A turbofan gas turbine engine 90, as shown in figure 4, comprises in axial flow series an inlet 92, a fan section 94, a compressor section 96, a combustion section 98, a turbine section 100 and an exhaust 102. The compressor section 96 comprises a rotor blade tip clearance control as shown in figure 2 or figure 3.

The ceramic fibres may be silicon nitride, silicon carbide, boron, alumina or other suitable fibres.

The metal disc may comprise titanium, titanium aluminide, an alloy of titanium, or any suitable metal, alloy or intermetallic which is capable of being bonded.

The annular spacer may comprise titanium, titanium aluminide, an alloy of titanium, or any suitable metal, alloy or intermetallic which is capable of being bonded.

If the annular spacer is too stiff the downstream compressor disc and compressor blades lie at an angle to the plane A, and the trailing edges of the tips of the compressor blades may rub the compressor casing because the annular spacer moves radially inwardly relative to the compressor discs. Additionally the clearance between the ribs on the annular spacer and the inner shrouds on the stator vanes will be too large. Thus the ring of fibres in the annular spacer must be selected to prevent rubbing of the trailing edges of the tips of the compressor blades and to prevent the clearance between the ribs on the spacer and the inner shrouds of the stator vanes being too large.

Although the invention has referred to compressor rotors and discs, the invention is equally applicable to gas turbine engine turbine rotors and discs. The invention is also applicable to other rotors or discs, for example steam turbines etc.

Claims:-

1. A rotor comprising a plurality of axially spaced rotor discs, each rotor disc having a plurality of rotor blades extending radially therefrom, a stator spaced from the rotor by a clearance, at least one annular spacer extending axially between and secured to an upstream rotor disc and a downstream rotor disc, the at least one annular spacer being fibre reinforced to limit the radial movement thereof and hence the clearance between the rotor and the stator.

2. A rotor as claimed in claim 1 wherein the stator comprises a casing surrounding and spaced radially from the rotor blades by a clearance, the at least one annular spacer being fibre reinforced to limit the radial movement thereof and hence the clearance between the rotor and the stator.

3. A rotor as claimed in claim 1 or claim 2 wherein the stator comprises a stator vane assembly surrounding and spaced radially from the annular spacer by a clearance, the at least one annular spacer being fibre reinforced to limit the radial movement thereof and hence the clearance between the rotor and the stator.

4. A rotor as claimed in claim 3 wherein the annular spacer has at least one circumferentially extending rib to define a labyrinth seal with the stator vane assembly.

5. A rotor as claimed in any of claims 1 to 4 wherein the rotor discs are metal discs and the at least one annular spacer is a fibre reinforced metal spacer.

6. A rotor as claimed in claims 5 wherein the rotor discs are fibre reinforced metal discs, the fibre reinforced metal disc being reinforced by at least one ring of fibres.

7. A rotor as claimed in claim 6 wherein the fibre reinforced metal disc has an axis of rotation, the fibre reinforced metal disc has a first ring of fibres at a first

radial distance from the axis of rotation and a second ring of fibres at a second radial distance from the the axis of rotation, and the second radial distance is greater than the first radial distance.

8. A rotor as claimed in claim 7 wherein the fibre reinforced metal disc comprises a hub, a rim and a diaphragm extending radially between the hub and the rim, the first ring of fibres is in the hub of the fibre reinforced metal disc and the second ring of fibres is in the rim of the fibre reinforced metal disc.

9. A rotor as claimed in any of claims 6 to 8 wherein the fibre reinforced metal disc comprises titanium, titanium aluminide, an alloy of titanium, or any suitable metal, alloy or intermetallic which is capable of being bonded.

10. A rotor as claimed in any of claims 5 to 9 wherein the fibre reinforced metal spacer comprises titanium, titanium aluminide, an alloy of titanium, or any suitable metal, alloy or intermetallic which is capable of being bonded.

11. A rotor as claimed in any of claims 5 to 9 wherein the reinforcing fibres comprise silicon carbide, silicon nitride, boron, alumina or other suitable fibres.

12. A rotor as claimed in any of claims 1 to 11 wherein there are a plurality of annular spacers.

13. A rotor as claimed in any of claims 1 to 12 wherein the fibre reinforcement in the annular spacer is selected to provide sufficient stiffness to the annular spacer to minimise radially outward movement of the annular spacer relative to the upstream rotor disc and downstream rotor disc.

14. A rotor as claimed in claim 13 wherein the fibre reinforcement in the annular spacer is selected to provide sufficient stiffness to the annular spacer to match the

radially outward movement of the annular spacer, the upstream rotor disc and the downstream rotor disc.

15. A rotor as claimed in any of claims 1 to 12 wherein the fibre reinforcement is selected to provide sufficient stiffness to the annular spacer to produce radially inward movement of the annular spacer relative to the upstream rotor disc and downstream rotor disc.

16. A rotor as claimed in any of claims 1 to 15 wherein the rotor is a compressor rotor or a turbine rotor.

17. A rotor as claimed in any of claims 1 to 16 wherein the rotor is a gas turbine rotor.

18. A rotor substantially as hereinbefore described with reference to and as shown in figure 2 of the accompanying drawings.

19. A rotor substantially as hereinbefore described with reference to and as shown in figure 3 of the accompanying drawings.

20. A gas turbine engine comprising a rotor as claimed in any of claims 1 to 19.

ABSTRACT

A ROTOR

A rotor (40) comprises a plurality of axially spaced rotor discs (42,44), each rotor disc (42,44) has a plurality of rotor blades (48,50) which extend radially therefrom. A casing (52) surrounds and is spaced radially from the rotor blades (48,50) by a clearance (54,56). At least one annular spacer (46) extends axially between and is secured to an upstream rotor disc (42) and a downstream rotor disc (44). A stator vane assembly (60) surrounds and is spaced radially from the spacer (46) by a clearance (64). The at least one annular spacer (46) has a ring of fibres (72) to reinforce the annular spacer (46) to control the clearance (56) between the rotor blades (50) of the downstream rotor disc (44) and the casing (52) and the clearance (64) between the annular spacer (46) and the stator vane assembly (60) by preventing radial bowing of the spacer (46). This is applicable to gas turbine engine compressors and turbines.

(Figure 2)

Fig 1

1/

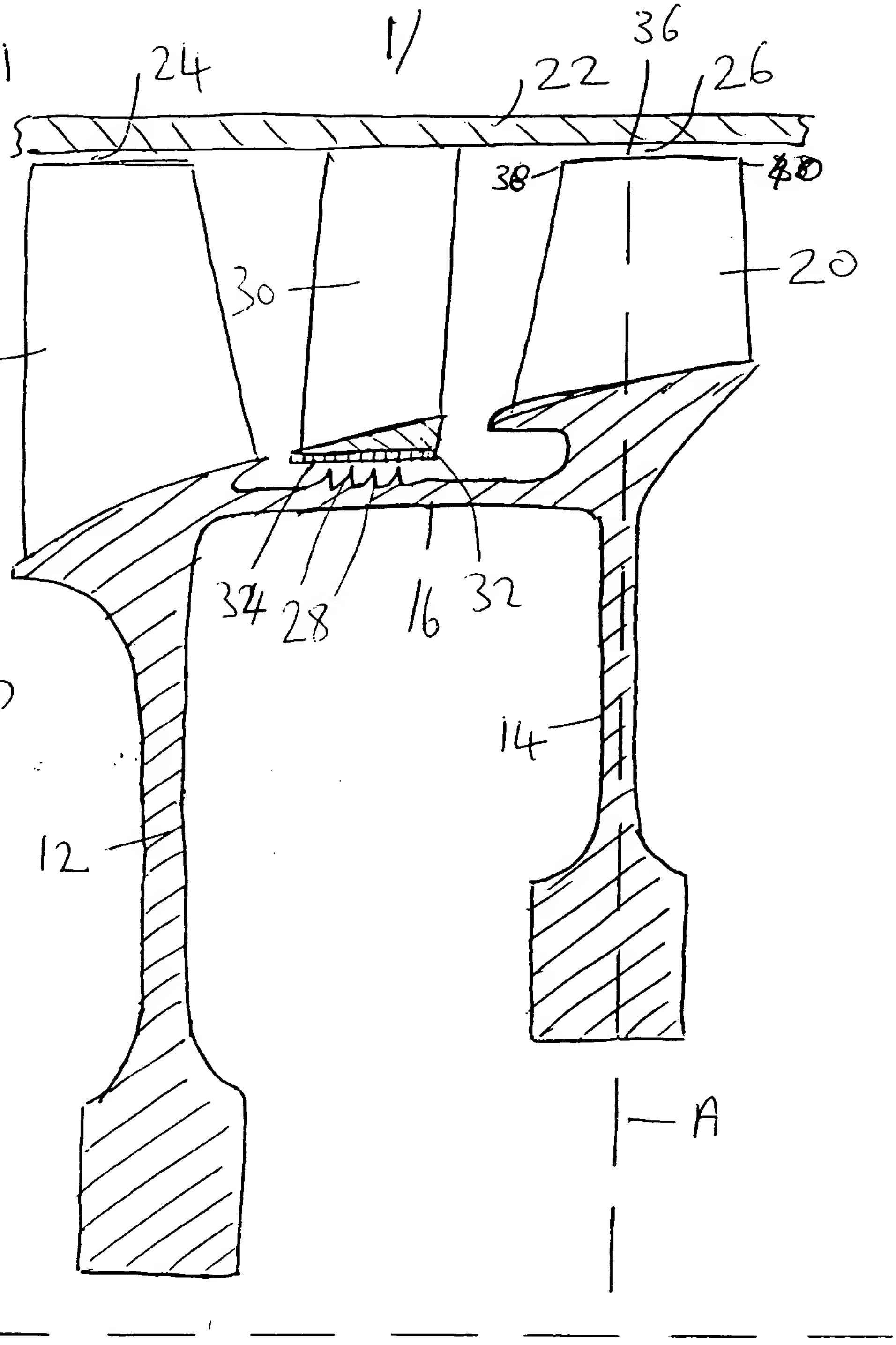

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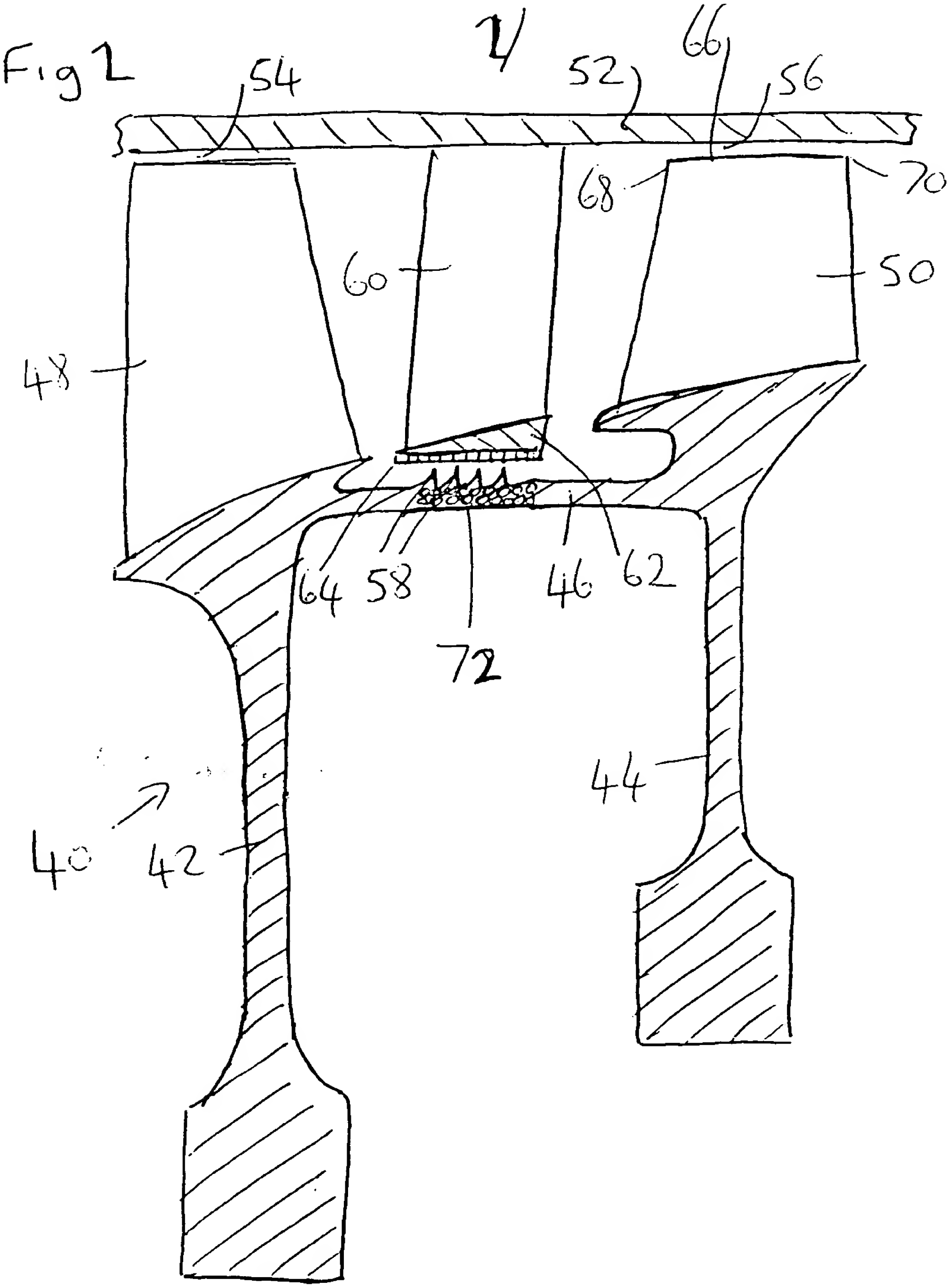
Fig 2



3/

Fig 3

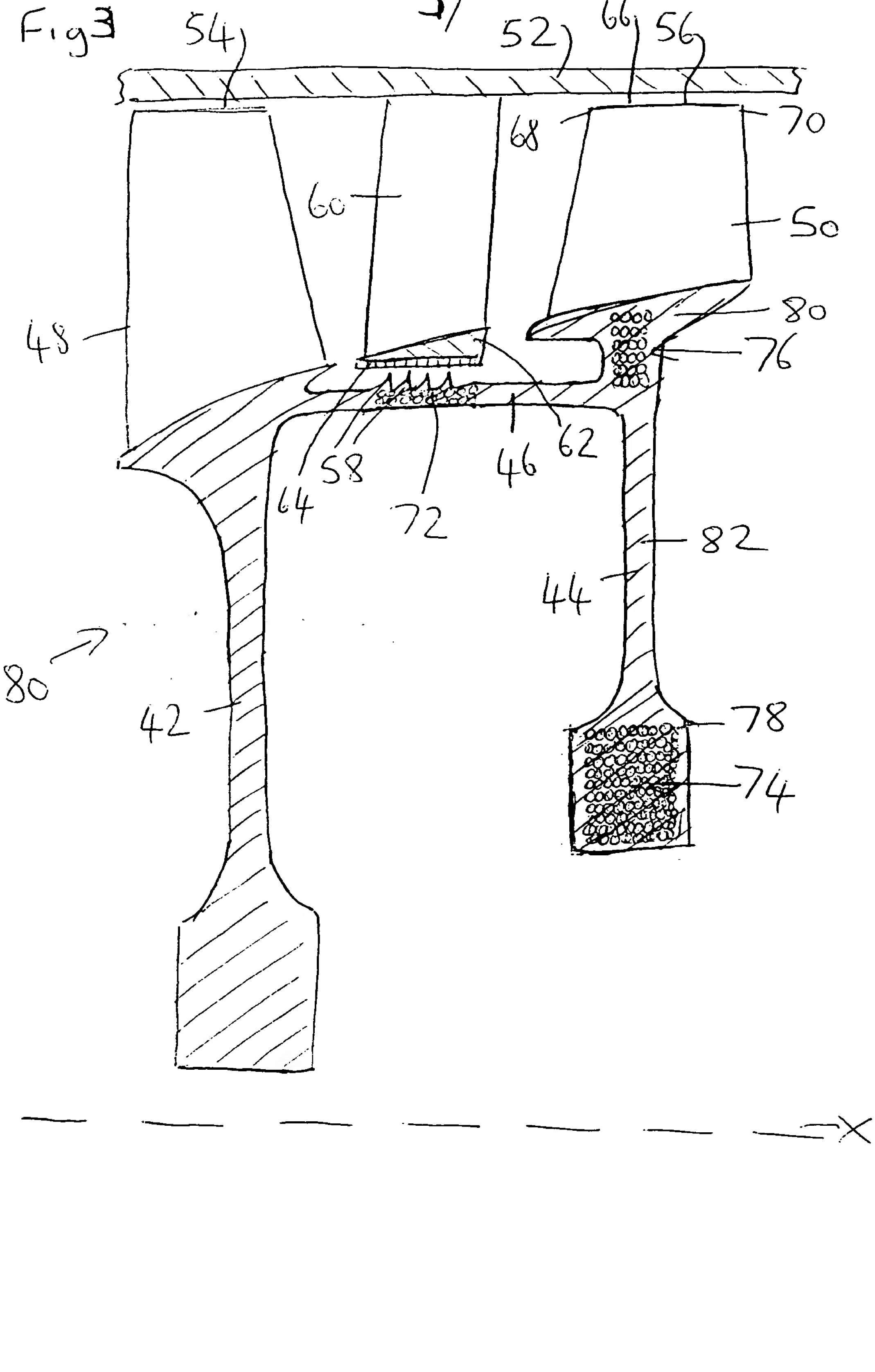


Fig 4